Goh, Kaichen & Yang, Jay (2014) Importance of sustainability-related cost components in highway infrastructure : perspective of stakeholders in Australia. *Journal of Infrastructure Systems*, *20*(1), 04013002.

http://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000152

Importance of Sustainability Related Cost Components in Highway Infrastructure: Perspective of Stakeholders in Australia

Kaichen Goh[1] and Jay Yang[2]

ABSTRACT

Highway infrastructure development typically requires major capital input. Unless planned properly, such requirements can cause serious financial constraints for investors. The push for sustainability adds a new dimension to the complexity of evaluating highway projects. Finding environmentally and socially responsible solutions for highway construction will improve its potential for acceptance by the society and in many instances, the infrastructure's life span. Even so, the prediction and determination of a project's long-term financial viability can be a precarious exercise. Existing studies in this area have not indicated details of how to identify and deal with costs incurred in pursuing sustainability measures in highway infrastructure. This paper provides insight into the major challenges of implementing sustainability in highway project development in terms of financial concerns and obligations. It discusses the results from recent research through a literature study and a questionnaire survey of key industry stakeholders involved in highway infrastructure development. The research identified critical cost components relating to sustainability measures based on perspectives of industry stakeholders. All stakeholders believe sustainability related costs are an integral part of the decision making. However, the importance rating of these costs is relative to each stakeholder's core business

[1] Senior Lecturer, Department of Construction Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), 86400, Parit Raja, Batu Pahat, Johor, Malaysia.
[2] Professor of Construction Engineering and Management, School of Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology, GPO Box 2434 Brisbane QLD4001 Australia.

objectives. This will influence the way these cost components are dealt with during the evaluation of highway investment alternatives and financial implications. This research encourages positive thinking among the highway infrastructure practitioners about sustainability. It calls for the construction industry to maximise sustainability deliverables while ensuring financial viability over the life cycle of highway infrastructure projects.

KEYWORDS

Highway, infrastructure, sustainability, engineering economics, stakeholders

INTRODUCTION

Highway infrastructure development and regeneration are gaining significance in many countries such as the USA, China and Australia. In coping with the export of resources and associated regional growth the Australian government has set up various plans to accelerate road infrastructure development and improvement (BTCE 2009). As the government commits to boosting the economy through national infrastructure projects, sustainability challenges need to be included in the equation. Sustainability is an evolving concept with changing implications and wide ranged interpretations in the built environment (Yang 2012). For highway infrastructure development, it calls for more resource-sufficient, cost-effective, environmentally-friendly and socially-acceptable solutions in both the construction and operation phases (Jha et al. 2012; Ramaswami and Rudolph 2009; Šelih et al. 2008). In many ways, environmental and social sustainability is becoming a matter of responsibility and operational practice for industry stakeholders and the government. Sustainability endeavours in highway development, for example, noise barrier installation, will require additional upfront capital input. This is often a concern for investors, owners and other stakeholders. Recent financial studies in Australia have revealed that more than a third of Australian local governments are financially constrained (PriceWaterhouseCoopers 2006). However, they have the on-going task of working with the federal government to develop and maintain highway infrastructure. To do so, they must ensure that adequate funding is in place for the long term. Therefore, early insight into the financial picture of pursuing sustainability has become an essential strategy for astute infrastructure investors and stakeholders.

Making an investment decision can be complicated when cost components related to sustainability are unclear. As highway infrastructure usually has a long-term life span, the evaluation of investment alternatives and project options requires tools and a systematic approach. Engineering economics is considered as a valuable approach to deal with public-sector investment evaluation and it often involves benefit-cost analysis and life-cycle cost analysis (Lee 2002). Life-cycle cost analysis (LCCA) provides valuable considerations on time, value for money, and reduction of running costs over time and conversion to a single current value or present worth for analysis (Ozbay et al. 2004). It can be used intermittently throughout the economic life of an asset such as a highway. In theory, LCCA can be regarded as a subset of benefit-cost analysis (BCA), with the latter being widely recognised as a useful framework for assessing the positive and negative aspects of prospective actions and policies, and for making the economic implications' alternatives an explicit part of the decision-making process (Carter and Keeler 2008; Jang and Skibniewski 2009).

In today's environment, all engineering economics approaches should incorporate the principles of sustainability. However, the difficulties in 'measuring sustainability' and the inconsistency in measurement standards often complicate the matter. Previous studies have shown ambiguities in identifying sustainability-related costs and impacts in highway development (Kendall et al. 2008; List 2007; Wilde et al. 2001; Zhang et al. 2008). Many previous studies tend to avoid such complexities by omitting social and environmental costs. This has resulted a knowledge gap (Figure 1).

Other problems also hinder the integration process. Collecting cost data is challenging because of the complexity of sustainability in highway projects. It often has different priorities, perspectives, and interpretations depending on the projects, organisations and stakeholders. Costs related to environmental and social measures eventually involve ‘soft’ factors that display inconsistency in measurement approaches (Surahyo and El-Diraby 2009). Existing BCA and LCCA models for highways are primarily concerned with direct market costs, such as road construction and maintenance costs and crash damages, and how these vary depending on roadway conditions (Chou et al. 2006; Gerbrandt and Berthelot 2007; List 2007; Madanu et al. 2009; Ugwu et al. 2005). Early attempts to address the new sustainability aspects differ significantly in their consideration of environmentally and socially-related costs (Quinet 2004; Surahyo and El-Diraby 2009). Benefits and costs are often articulated in money terms and are in sync with the time value of money, so that all flows of benefits and project costs over time are expressed on a common basis in terms of their “present value” (Lee 2002).

This paper examines current views and practices of industry stakeholders in regard to integrating sustainability into the long-term financial predictions and evaluation for highway infrastructure projects. It discusses a research project that identifies the importance of sustainability-related cost components in highway infrastructure provisions. In the research, a range of cost components were identified and evaluated by Australian highway industry practitioners based on their real-life experiences. The most significant cost components were incorporated into new modules as part of a developing financial decision support model expanded from existing studies to incorporate the costs associated with sustainability commitments. The research seeks to bridge some of the knowledge gaps between sustainability endeavours and long-term financial investment decisions in highway infrastructure in the Australian context.

SIGNIFICANCE OF SUSTAINABILITY-RELATED COST COMPONENTS IN HIGHWAY INVESTMENT

Highway projects are long-term assets. Strategic plans should set out capital expenditure requirements for the next 25-50 years to maintain service levels and long-term financial viability (Gerbrandt and Berthelot 2007; Gransberg and Molenaar 2004). Cash-flow constraints at points in time should also be resolved through long-term financial planning. Decision tools are required to evaluate investment decisions.

Realising the advantages of pursuing sustainability, a number of research projects have attempted to investigate topics that bridge the gap between sustainability and highway infrastructure. For example, Huang and Yeh (2008) have implemented an assessment rating framework for green highway projects. In the study, the framework has been developed to analyse and measure the achievement of sustainability in the highway infrastructure by using several indicators. Ugwu et.al (2006a; 2006b) found that there is a need for methods and techniques that would facilitate sustainability assessment and decision-making at the various project level interfaces during the development phases of a project.

Although the sustainability concept is essential for current Australian highway infrastructure development, stakeholders also realise the importance of its long-term cost implications for investments. As decisions based solely on acquisition cost may not be effective in the long run, Surahyo and El-Diraby (2009) highlighted the need to assess both environmental and social costs in the construction, rehabilitation and operational phases of highway development. There is consensus among stakeholders that sustainability endeavours will have an impact on the developmental costs of highway infrastructure.

As sustainability is being increasingly emphasised in highway infrastructure, effective management of highway investment has become a crucial issue as highway funding to address the shortfall of funds at all levels of government (PriceWaterhouseCoopers 2006). In this regard, the engineering economics concept is applied in highway development to explore more efficient investments for stakeholder. It evaluates not only the initial construction cost of the highway infrastructure, but also all the associated maintenance costs during its service life.

The use of engineering economics in highway infrastructure seems established, but limitations in the current approaches still remain - they are not well-established and do not cover some critical issues in highway development. Wilde et al. (2001) reported that consideration of the social impacts of road construction, including health impacts of pollution emission and noise, was conversely independent of other costs and that these elements had not been incorporated into engineering economics.

The existing approaches tend to omit costs incurred for pursuing sustainability matters in the engineering economics calculation in highway infrastructure projects. These sustainability-related cost components include agency, social and environmental costs caused by the activities involved in highway construction and maintenance. As stated by Singh and Tiong (2005), user costs are social costs incurred by the highway user, and include accident costs, delay costs and vehicle operating costs (such as fuel, tires, engine oil and vehicle maintenance). These costs are increasingly important given that they will indirectly influence the financial budget for a long-term investment.

This study is motivated by the realisation of the need and potential to incorporate sustainability-related cost components into the highway investment decision, in order to capture the full costs of highway development under the increased pressure to achieve sustainability. To this end, all projects of highway development, whether for capacity building, new access or regeneration, have an obligation to respond to these cost components.

ASSESSING SUSTAINABILTY COSTS FOR HIGHWAY PROJECTS

Sustainability adds a new dimension to the evaluation of highway investments. However, the highway infrastructure sector's understanding of life cycle costs remains limited (List 2007; Wilde et al. 2001; Zhang et al. 2008). Practitioners' 'imperfect' perception of the merits of life-cycle costing and sustainability outcome appear to be the main cause (Chan et al. 2008; Cole and Sterner 2000).

According to Quinet (2004), existing studies consider environmental impacts, primarily air pollution, noise and water pollution, and land use impacts, as external costs. There also seem to be blurred boundaries in social and environmental costs for highway projects (Surahyo and El-Diraby 2009). Surahyo and El-Diraby (2009) highlighted the inconsistency in current estimation methods for highway construction, with a bias towards socioeconomic, technological or engineering approaches. The complexity of sustainability and the broad implications and interests in financial issues made it difficult for past research to create consistent estimation methods.

Studies on sustainability-related cost components in highway infrastructure development continue to evolve (List 2007; Surahyo and El-Diraby 2009). While real-world perspectives of life-cycle costs remain scarcely reported, past studies have highlighted the need to consider appropriate methodologies in dealing with these issues.

Based on a review of recent literature, this paper suggests three categories of costs relating to sustainability measures and considerations:

- Agency costs such as those for initial construction, maintenance, pavement upgrade and end-of-life costs (Bradbury et al. 2000; Rouse and Chiu 2008; Tighe 2001);
- Social costs such as items from vehicle operation, travel delay, social impact and road accidents (Gilchrist and Allouche 2005; Gorman 2008; Surahyo and El-Diraby 2009; Winston and Langer 2006); and
- Environmental costs such as those dealing with noise, air quality, water quality, resource consumption and pollution damage from agency activities and solid waste generation (Ahammed and Tighe 2008; Steen 2005; Surahyo and El-Diraby 2009; Ugwu et al. 2005).

These costs have been compared with and checked against Australian highway infrastructure characteristics and terminologies. With some minor adjustments, a set of key cost components relating to sustainability measures was established. The three main cost categories of agency, social and environmental costs were expanded into 14 main factors with 42 sub factors for in-depth investigation. Table 1 sets out the sustainability-related cost components for highway infrastructure. Surveys were conducted to study local infrastructure scenarios, collect opinions from practitioners and develop a decision model for cost predictions and financial management.

RESEARCH DESIGN AND DEVELOPMENT

Questionnaire surveys are effective in gathering information about the characteristics, actions, or opinions of a large group of people (Creswell 2009). In this research, a questionnaire survey was conducted to assess the importance of sustainability-related cost components in highway infrastructure. The questionnaire used in this research was based on a combination of the literature review, preliminary model development, and also the identification of sustainability-related cost components in highway infrastructure.

In this research, three main construction industry players involved in highway projects, namely consulting companies, contractors and government agencies from Australia, were included. The respondents include senior practitioners and stakeholders who have substantial working experience in highway infrastructure projects. They play an important role in the construction industry because they are the decision-makers in highway investments. Consequently, these stakeholders also have more concerns about the economic dimension of highway construction projects.

A pilot study was done with three academic and six industry experts. This helped finalise the 42 sub-factors as sustainability-related cost components in the questionnaire survey. Targeted stakeholders included government and client representatives, builders, designers, project managers, quantity surveyors, planners, contractors and subcontractors involved in highway projects. The questionnaire respondents were selected at random from industry databases in:

- The National Innovative Contractors Database by the Cooperative Research Centres for Construction Innovation.

- Directories from the Australian Institute of Quantity Surveyors.
- Directories from the Association of Consulting Engineers Australia.

These databases are commonly considered as the most authoritative and complete for the infrastructure sector. Therefore, the sample is a fair representatation of the Australian construction industry stakeholders. Using the databases, 75 organisations throughout Australia are selected due to their recent involvement in highway projects. The questionnaire survey was administered online in 2011. Through random sampling among contacts listed in these organisations, 150 potential respondents were selected and approached for the questionnaire survey. 71 questionnaires were returned with 9 incomplete. As a result, the useable response rate was 42% or 62 questionnaires. Of the 62 industry respondents, all of them were from the top (78%) and middle (22%) management level, holding positions such as General Managers, Finance Directors or Project Managers respectively. All the participants had experience working in highway projects, with many over 20 years. The majority of participants were involved in highway design and construction activities (50%). A small number of participants were also involved in highway maintenance and extension works (19%); others engaged in smaller scale of construction, extension and maintenance works (31%). Most of the respondents came from the project management team (40%), others were client representatives, design consultants and construction contractors (20% each). Together they serve as the decision makers in highway development and as such, have more experience in the economic dimensions of highway projects. As highway development work is often at a national level and undertaken across state boundaries, the current geographical location of these respondents was not considered as important. Nevertheless, more than half (53%) of them also had work experience in government agencies throughout Australia. This background ensures the perspectives and viewpoints collected through the survey are representative of the real-world scenarios and needs across Australia.

Statistical Measures and Analysis

Mean indexing and the t-test are widely used in exploratory and descriptive data analysis (Ahuja et al. 2009; Shehu and Akintoye 2010; Yang and Peng 2008). In the questionnaire survey, the level of importance was based on the respondents' professional judgment on a given five-point Likert scale from 1 to 5 (where 1 was "not important at all" and 5 was "very important"). Respondents were asked to consider the importance of the sustainability related cost components based on project level considerations from their work experience. Specific descriptions were used to define the questions to ensure that interviewees understood and responded accordingly. The critical rating was set at 3.75 representing "important" or "most important". Likert scales facilitate the quantification of responses so that statistical analysis can be undertaken. Perceptions of differences between participants can also be observed. This study also employed descriptive statistics to analyse the survey results on the critical cost components. Prior to proceeding with the analysis, a Cronbach α reliability analysis was conducted. Data reliability was set for $\alpha \geq 0.7$ as recommended (Chan et al. 2010; Yip Robin and Poon 2009). Yang and Peng (2008) suggest that in the early stages of research on predictor tests or hypothesised measures of a construct, reliability of $\alpha \geq 0.7$ or higher will be adequate. In this research, $\alpha = 0.948$.

T-test analysis has been used by past studies to identify relative importance between variables (Ekanayake and Ofori 2004; Shehu and Akintoye 2010; Wong and Li 2006). The rule of the t-test in this survey analysis was that cost factors with a rank value larger than 3.75 were considered critical. The null hypothesis *(*H_0*:* $\mu_1<\mu_0$*)* against the alternative hypothesis *(*H_1*:* $\mu_1>\mu_0$*)* was tested, where μ_1 represented the critical rating above which the indicators were considered as "important", and μ0 represented the mean score of the survey that shows the rating below which the indicators were considered as "less important". The value of μ_0 was fixed at 3.75. The decision rule was to reject H_0 when the result of the observed t-values (t_0) (Eq. (1)) was larger than the critical t-value (t_C) (Eq. (2)) as shown in Eq. (3).

$$t_0 = \frac{\bar{x} - \mu_0}{SD/\sqrt{n}} \tag{1}$$

$$t_c = t_{(n-1,\alpha)} \tag{2}$$

$$t_0 > t_c \tag{3}$$

where $\bar{x}$ is the sample mean, SD/ $\sqrt{n}$ is the estimated standard error different mean score (SD is the sampled standard deviation of difference score in the population, n is the sample size (62 in this study), *n-1* represents the degree of freedom, and α represents the significant level which is set at 5% (0.05).

The criticality of cost components in this study was examined using Eqs. (2) and (3). If the observed t-value was larger than the critical t-value $t_0>t_C$, $t_{(61,0.05)} = 1.671$ at 95% confidence interval, then H_0 for which the indicator was "moderately important", "less important" and "not important" was rejected, and only the H_1 was accepted. If the observed t-value of the mean ratings weighted by the respondents was less than the critical t-values ($t_0 < t_C$), the H_0 that was "less important" and "not suitable" only was accepted.

RESULTS

The questionnaire survey focused on identifying the critical cost components of sustainability measures that industry stakeholders believe should be incorporated into highway investment decisions. The questions in the questionnaire focused on the level of importance of three groups of sustainability-related cost components: agency, social, and environmental cost components. The questions were designed to identify the importance of these three categories of cost components in long-term financial management as highlighted in the literature review.

The three sections focus on different aspects of sustainability-related cost components when selecting a highway infrastructure project and making highway investment decisions. The agency, social, environmental cost component sections aim to explore the perspective of industry stakeholders' regarding the level of importance of these costs in highway investment. Meanwhile, the open questions seek to explore the comments and opinions of the stakeholders towards implementation of sustainability-related cost components in the long term financial management of a highway. The supplement at the end of the questionnaire was designed to gather information about the participants' background for statistical purposes.

The questionnaire was developed using a multiple-choice format. The questionnaire also included one open-ended question to allow respondents with relevant experience in highway development to submit additional comments and outline other problems they have experienced in the long-term financial management of highway projects. Based on the data from the questionnaire survey, stakeholders' perspectives on the importance of cost components are presented in Table 2.

Sustainability-related cost components: Perspective of industry stakeholders

The results indicate that the importance level of sustainability-related cost components, according to the consultants, were different than the importance level according to other stakeholders. Among the consultants, the highest rated costs were material costs (mean = 4.57), plant and equipment costs (mean = 4.36) and labour costs (mean = 4.07) in the agency category. Vehicle operating costs (mean = 3.79), traffic congestion (mean = 3.79) and road accident-economic value of damage (mean = 3.71) were the highest rated in the social category. Waste management (mean = 3.93), ground extraction (mean = 3.86), disposal of material costs (mean = 3.86) and hydrological impacts (mean = 3.86) were rated the highest in the environmental category.

For contractors, the most important cost components were those that threatened their profit level, with materials (mean = 4.50), plant and equipment (mean = 4.19), rehabilitation (mean = 3.94) and recycling costs (mean = 3.94) rated as important in the agency category. The road accident-internal costs (mean = 4.25), traffic congestion (mean = 4.00) and external costs (mean = 3.88) were rated the most significant in the social category. The disposal of materials (mean = 4.13), ground extraction (mean = 4.06) and waste management costs (mean = 4.00) were classified as critical in the environmental category.

For government agencies and local authorities, the ten costs rated highest in importance were those in the category of agency costs, namely, materials (mean = 4.30), major maintenance (mean = 4.24) and rehabilitation costs (mean = 4.21). In the social category, road accident costs, namely, internal costs (mean = 4.45), external costs (mean = 4.39) and the economic value of damage (mean = 4.00) were rated highest in importance. In the environmental category, hydrological impacts (mean = 4.36), loss of wetland (mean = 4.24) and cost of barriers (mean = 4.21) were the most important.

A general observation of the results is that the cost components rated most highly by the respondents tended to be those that were paramount to their specific business objectives. Analysis of the results reveals that the most important cost components were centred on three major sustainability aspects, namely, agency, social and environmental cost issues. The following sections discuss these findings in detail.

DISCUSSION

The most critical cost components in highway investments with sustainability objectives were identified. The results on the critical cost components were indicated by the t-values which were higher than the cut-off t-value (1.6710) offering supporting evidence for the importance of these cost components. The top ten rated cost components were identified and validated by industry stakeholders as shown in Figure 2.

Agency costs category

Agency costs consist of all expenses generated by the highway agencies' activities throughout the overlay system lifetime. These typically include construction and preservation costs such as material, plant and equipment and labour costs. Consultants were more concerned with the initial construction costs in highway development. They rated materials (mean = 4.57; rank = 1), plant and equipment (mean = 4.36; rank = 2) and labour costs (mean = 4.07; rank = 3) as the most important. Consultants are mostly involved at the front-end of project development and would therefore tend to focus on the initial costs rather than on the life-cycle benefits for highway operation and maintenance. Conversely, the consultants in this study were less interested in cost items such as pavement extension (mean = 2.86; rank = 9) and demolition (mean = 2.86; rank = 9) as required in LCCA for highway projects. According to them, by the end of the pavement's life, major rehabilitation works are usually required to improve the pavement quality.

Respondents in the government agency group and local authority groups rated major maintenance (mean = 4.24) as the second most important cost, while the contractors rated rehabilitation costs (mean = 3.94) as the third most important in the agency costs category. Contractors reported that maintenance and rehabilitation activities often involve a significant cost throughout the highway life span. Rehabilitation activities are important to ensure the optimisation of highway pavement performance (Chung et al. 2006). However, perhaps due to limited funding in today's economic climate, government agencies and local authorities considered that the greatest task in managing highway infrastructure was the prioritisation of maintenance and repair expenditure. As highway infrastructures approach the end of their design lives, there is an increasing demand for new construction, rehabilitation, maintenance and repairs to maintain service levels.

Some factors were more important than others according to different stakeholders. For example, costs for pavement recycling was ranked as the third most important factor according to contractors but only ranked eighth in importance by government agencies and local authorities (mean = 3.21) and consultants (mean = 3.43). According to Widyatmoko (2008), recycled materials are more cost effective compared to conventional new materials. Recycled materials also provide similar performance in pavement. This shows that contractors, at the forefront of the work field, are increasingly concerned with economic advantage, placing an emphasis on recycled material.

Social costs category

In relation to road accidents, internal costs emerged as the most important theme in the social category. Government agencies and local authorities (mean = 4.45; rank = 1) and the contractor group (mean = 4.25; rank = 1) were most concerned with road safety. According to them, the main reason for highway infrastructure development was to improve community mobility and road safety. This is supported by past research. According to Park et al. (2012), the consideration of factors such as pavement width can significantly reduce the rate of road accidents. Highway construction needs to improve general access for the community while highway upgrades, maintenance and rehabilitation should continue to improveme road safety. Currently, decisions on highway design are often based on the safety of road users, rather than the available financial resources. Thus, road accident costs are a primary concern among the social aspects of LCCA for highway projects.

Vehicle operation (mean = 3.79; rank = 1) and traffic congestion (mean = 4.00; rank = 2) received high importance ratings among costs in the social category from the contractors and consultant groups. These costs indirectly influence the overall cost of a highway throughout its lifetime and should be taken into account in LCCA for highway projects. Heavy traffic tends to degrade the public realm (public spaces where people naturally interact) and in other ways reduces community cohesion (Litman 2007). Highway traffic certainly involves traffic delay costs to users who have been mathematically modeled and evaluated based on simplifying assumptions (Jiang and Adeli 2003). While road users incur these costs, Wilde et al. (2001), Ozbay et al. (2004) and Eliasson (2009) believe that costs occurred in lost travel time may exceed an agency's construction cost by a substantial amount, particularly in urban areas.

Renewal and regeneration works are needed for highway infrastructure at some point in time and will require funds. It is a challenge for industry stakeholders to optimise the desired service levels while minimising life-cycle costs for highway infrastructure.

Environmental costs category

Highway systems cause a number of impacts on the environment. Costs related to environmental problems vary depending on the situation and the nature of the project (Surahyo and El-Diraby 2009). Water pollution (such as hydrological impacts) (mean = 4.36; rank = 1) and loss of wetlands (mean = 4.24; rank = 2) were rated as the most important costs by the participants representing government agencies and local authorities. Such problems can result in polluted surfaces and groundwater, contaminated drinking water, increased flooding and flood control, loss of unique natural features, and aesthetic losses. Quantifying these costs is challenging. For example, determining how many motor vehicles contribute to water pollution problems can be difficult since the impact is often diffused and cumulative.

Waste management costs were rated as significant by contractors (mean = 4.00; rank = 3) and consultants (mean = 3.93; rank = 1). These costs are usually generated during the construction, maintenance and rehabilitation stages of highway development. They are significant because engineers make early decisions on design configurations, construction methods/processes and material specifications. Such decisions often have major impacts on the whole-of-life cost. Material reuse, recycling and innovation in methods and processes will help reduce these costs. Legislation and policies can help ensure that the disposal of materials is properly managed (Hao et al. 2007). In some cases, legislation and carrying out proper planning makes it essential for stakeholders to prepare a relevant budget to manage the disposal of solid waste.

RESEARCH LIMITATIONS

The sampling process was enabled through industry databases typically listing senior managerial roles. This ensured a relatively high profile of respondents, which suited this research well as it explored key stakeholder perceptions. In roles of senior to top managers, the respondents were asked to reflect on their years of experience and project level views and to discard any performance indicators specific to each organisation.

The limited number of contacts listed in industry databases has resulted in a small sample population, which presents a research limitation, as larger samples would normally yield more data to work from. However, this problem is offset by the seniority of the respondents ,their associated broad viewpoints and that they have made top in real rather than speculative projects. Nevertheless, future work could approach the issue with a wider range of practitioners. In addition, to make the research results applicable to other countries, regional differences due to distinctive economic, cultural and political environments can be prospective topics of study.

CONCLUSION

Sustainability has become one of the primary concerns within the construction industry. Compared to other sectors, the highway infrastructure sector also faces tough monetary challenges due to huge levels of funding required for the project life cycle. Stakeholders and investors need strategies to maintain financial viability as sustainability measures are increasingly introduced into the design, planning, construction and operation phases. According to the industry practitioners, consideration of sustainability-related cost components through long-term financial management can significantly improve evaluation credibility for highway investments. It can also potentially reduce project risk and therefore, promote further sustainability input by the stakeholders.

Current literature on sustainability-related costs is mostly related to building construction. However, the complex and dynamic nature of highway projects translates to an even higher level of investment risk. Therefore, it is crucial to explore the relative importance of potential cost components and focus on the critical costs in order to improve long-term investment decision making. This study investigated these issues based on a survey of the perceptions, knowledge and experience of Australian industry stakeholders.

The research reveals the most critical cost components in highway investments in the Australian infrastructure context. The perceptions of consultants and contractors are relatively similar. For example, both groups classify material, plant and equipment costs as the top components in highway investment. There are some differences in the rating of the importance of cost components between stakeholders. Government agencies and local authorities have different opinions compared to the other groups. This can be explained by the fact that they are often the main investors in public highway infrastructure. Different professions and organisations have their own priority goals and needs, and such differences can affect the handling of these cost components in highway investment decisions. However, all stakeholders surveyed in this study firmly believe that sustainability-related cost components are vital to decision making for highway development.

The identified cost components are being further investigated through interviews and a case study, which aim to identify specific methods of predicting and controlling these costs. It is anticipated that new highway investment evaluation models can be formulated to predict holistic financial models and sustainability deliverables in highway infrastructure.

REFERENCES

Ahammed, M. A., and Tighe, S. L. "Quiet Pavements: A Sustainable and Environmental Friendly Choice."

Ahuja, V., Yang, J., and Shankar, R. (2009). "Study of ICT adoption for building project management in the Indian construction industry." Automation in Construction, 18(4), 415-423.

Bradbury, A., Kazmierowski, T., Smith, K., and VonQuintas, H. "Life Cycle Costing of Freeway Pavements In Ontario."

BTCE (2009). "Public Road-Related Expenditure and Revenue in Australia (2009 Update)." Bureau of Transport Economics (BTE) Publication Summary.

Carter, T., and Keeler, A. (2008). "Life-cycle cost-benefit analysis of extensive vegetated roof systems." Journal of Environmental Management, 87(3), 350-363.

Chan, A., Keoleian, G., and Gabler, E. (2008). "Evaluation of Life-Cycle Cost Analysis Practices Used by the Michigan Department of Transportation." Journal of Transportation Engineering, 134(6), 236-245.

Chan, D. W. M., Chan, A. P. C., Lam, P. T. I., and Wong, J. M. W. (2010). "An empirical survey of the motives and benefits of adopting guaranteed maximum price and target cost contracts in construction." International Journal of Project Management, In Press, Corrected Proof.

Chou, J.-S., Peng, M., Persad, K., and O'Connor, J. (2006). "Quantity-Based Approach to Preliminary Cost Estimates for Highway Projects." Transportation Research Record: Journal of the Transportation Research Board, 1946(-1), 22-30.

Chung, S.-H., Hong, T.-H., Han, S.-W., Son, J.-H., and Lee, S.-Y. (2006). "Life cycle cost analysis based optimal maintenance and rehabilitation for underground infrastructure management." KSCE Journal of Civil Engineering, 10(4), 243-253.

Cole, R. J., and Sterner, E. (2000). "Reconciling theory and practice of life-cycle costing." Green Procurement of Buildings.

Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches, Sage Publications, Inc.

Ekanayake, L., and Ofori, G. (2004). "Building waste assessment score: design-based tool." Building and Environment, 39(7), 851-861.

Eliasson, J. (2009). "A cost-benefit analysis of the Stockholm congestion charging system." Transportation Research Part A: Policy and Practice, 43(4), 468-480.

Gerbrandt, R., and Berthelot, C. (2007). "Life-Cycle Economic Evaluation of Alternative Road Construction Methods on Low-Volume Roads." Transportation Research Record, 1989(-1), 61-71.

Gilchrist, A., and Allouche, E. N. (2005). "Quantification of social costs associated with construction projects: state-of-the-art review." Tunnelling and Underground Space Technology, 20(1), 89-104.

Gorman, M. F. (2008). "Evaluating the public investment mix in US freight transportation infrastructure." Transportation Research Part A: Policy and Practice, 42(1), 1-14.

Gransberg, D. D., and Molenaar, K. R. (2004). "Life-Cycle Cost Award Algorithms for Design/Build Highway Pavement Projects." Journal of Infrastructure Systems, 10(4), 167-175.

Hao, J. L., Hills, M. J., and Huang, T. (2007). "A simulation model using system dynamic method for construction and demolition waste management in Hong Kong." Construction Innovation, 7(1), 7-21.

Huang, R. Y., and Yeh, C. H. (2008). "Development of an assessment framework for green highway construction." Journal of the Chinese Institute of Engineers, 31(4), 573-585.

Jang, W.-S., and Skibniewski, M. J. (2009). "Cost-Benefit Analysis of Embedded Sensor System for Construction Materials Tracking." Journal of Construction Engineering and Management, 135(5), 378-386.

Jha, M. K., Shariat, S., Abdullah, J., and Devkota, B. (2012). "Maximizing Resource Effectiveness of Highway Infrastructure Maintenance Inspection and Scheduling for Efficient City Logistics Operations." Procedia-Social and Behavioral Sciences, 39, 831-844.

Jiang, X., and Adeli, H. (2003). "Freeway Work Zone Traffic Delay and Cost Optimization Model." Journal of Transportation Engineering, 129(3), 230-241.

Kendall, A., Keoleian, G. A., and Helfand, G. E. (2008). "Integrated Life-Cycle Assessment and Life-Cycle Cost Analysis Model for Concrete Bridge Deck Applications." Journal of Infrastructure Systems, 14, 214.

Lee, D. (2002). "Fundamentals of Life-Cycle Cost Analysis." Transportation Research Record: Journal of the Transportation Research Board, 1812(-1), 203-210.

List, G. (2007). "A model for life cycle evaluation of highway investments." Structure & Infrastructure Engineering: Maintenance, Management, Life-Cycl, 3(2), 95 - 101.

Litman, T. (2007). "Socially optimal transport prices and markets: principles, strategies and impacts." Social Research in Transport (SORT) Clearinghouse, 300.

Madanu, S., Li, Z., and Abbas, M. (2009). "Life Cycle Cost Analysis of Highway Intersection Safety Hardware Improvements." Journal of Transportation Engineering, 1, 51.

Ozbay, K., Jawad, D., Parker, N., and Hussain, S. (2004). "Life-Cycle Cost Analysis: State of the Practice Versus State of the Art." Transportation Research Record: Journal of the Transportation Research Board, 1864(-1), 62-70.

Park, E. S., Carlson, P. J., Porter, R. J., and Andersen, C. K. (2012). "Safety effects of wider edge lines on rural, two-lane highways." Accident Analysis & Prevention.

PriceWaterhouseCoopers (2006). "National Financial Sustainability Study of Local Government." Australian Local Government Association of Australia, Canberra, 6.

Quinet, E. (2004). "A meta-analysis of Western European external costs estimates." Transportation Research Part D, 9(6), 465-476.

Ramaswami, A., and Rudolph, L. (2009). "PROGRAM PLAN FOR THE CENTER FOR SUSTAINABLE INFRASTRUCTURE SYSTEMS (CSIS)."GAANN & IGERT Program in Sustainable Urban Infrastructure.

Rouse, P., and Chiu, T. (2008). "Towards optimal life cycle management in a road maintenance setting using DEA." European Journal of Operational Research, In Press, Corrected Proof.

Šelih, J., Kne, A., Srdić, A., and Žura, M. (2008). "Multiple□criteria decision support system in highway infrastructure management." Transport, 23(4), 299-305.

Shehu, Z., and Akintoye, A. (2010). "Major challenges to the successful implementation and practice of programme management in the construction environment: A critical analysis." International Journal of Project Management, 28(1), 26-39.

Singh, D., and Tiong, R. L. K. (2005). "Development of life cycle costing framework for highway bridges in Myanmar." International Journal of Project Management, 23(1), 37-44.

Steen, B. (2005). "Environmental costs and benefits in life cycle costing." Management of Environmental Quality: An International Journal, 16(2), 107-118.

Surahyo, M., and El-Diraby, T. E. (2009). "Schema for Interoperable Representation of Environmental and Social Costs in Highway Construction." Journal of Construction Engineering and Management, 135(4), 254-266.

Tighe, S. (2001). "Guidelines for Probabilistic Pavement Life Cycle Cost Analysis." Transportation Research Record: Journal of the Transportation Research Board, 1769(-1), 28-38.

Ugwu, O. O., Kumaraswamy, M. M., Kung, F., and Ng, S. T. (2005). "Object-oriented framework for durability assessment and life cycle costing of highway bridges." Automation in Construction, 14(5), 611-632.

Ugwu, O. O., Kumaraswamy, M. M., Wong, A., and Ng, S. T. (2006a). "Sustainability appraisal in infrastructure projects (SUSAIP): Part 1. Development of indicators and computational methods." Automation in Construction, 15(2), 239-251.

Ugwu, O. O., Kumaraswamy, M. M., Wong, A., and Ng, S. T. (2006b). "Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design." Automation in Construction, 15(2), 229-238.

Widyatmoko, I. (2008). "Mechanistic-empirical mixture design for hot mix asphalt pavement recycling." Construction and Building Materials, 22(2), 77-87.

Wilde, W. J., Waalkes, S., and Harrison, R. (2001). "Life Cycle Cost Analysis of Portland Cement Concrete Pavements." Research Report, 167205-167201.

Winston, C., and Langer, A. (2006). "The effect of government highway spending on road users' congestion costs." Journal of Urban Economics, 60(3), 463-483.

Wong, J., and Li, H. (2006). "Development of a conceptual model for the selection of intelligent building systems." Building and Environment, 41(8), 1106-1123.

Yang, J. (2012). "Editorial: Promoting integrated development for smart and sustainable built environment." Smart and Sustainable Built Environment, 1(1), 1-1.

Yang, J. B., and Peng, S. C. (2008). "Development of a customer satisfaction evaluation model for construction project management." Building and Environment, 43(4), 458-468.

Yip Robin, C. P., and Poon, C. S. (2009). "Cultural shift towards sustainability in the construction industry of Hong Kong." Journal of Environmental Management, 90(11), 3616-3628.

Zhang, H., Keoleian, G. A., and Lepech, M. D. (2008). "An integrated life cycle assessment and life cycle analysis model for pavement overlay systems." Life-Cycle Civil Engineering, 907-915.